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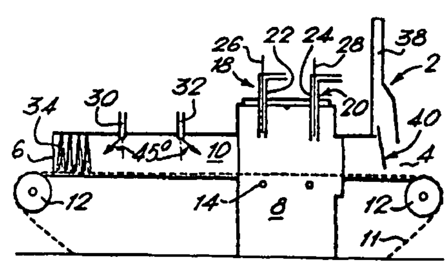
(54) **Heat treatment of metals.**

(57) Workpieces to be heat treated (for example to be annealed or sintered) are passed through a continuous furnace having in sequence, an entrance, a thermal treatment region, a cooling region and an exit. Ingress of air into the furnace through the entrance and exit is prevented. Typically the cooling region is provided at its exit end with one or more curtains or partitions providing a physical obstruction to the flow of air into the furnace and a flow of non-reactive gas (eg nitrogen) also to inhibit ingress of air. The curtains or partitions may form one or more chambers with the furnace and the nitrogen supplied to such chamber or chambers. Non-reactive gas and reducing gas (eg hydrogen) are introduced into the furnace to provide substantially non-oxidising conditions therein. The flow regimen is such that atmosphere or different compositions are created in the thermal treatment and cooling regions. By severely limiting ingress of air into the furnace and creating eg differential hydrogen concentrations along the furnace overall consumptions of gas may be considerably reduced.



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DESCRIPTION OF THE INVENTION

HEAT TREATMENT OF METALS

This invention relates to the heat treatment of metals. In performing heat treatment processes such as annealing, spheroidising, sintering, brazing, malleabilising and hardening, it is generally desirable to perform the treatment in a furnace under a reducing or non-oxidising atmosphere. The heat treatment may be performed on a batch or continuous basis. Continuous heat treatment furnaces are typically open-ended. They have an inlet for the metal or work to be heat treated, a thermal treatment region, a cooling region, and an outlet for the work. The work is advanced through the furnace at a chosen rate so that it is moved through the thermal treatment zone where it is raised to the necessary treatment temperature and is then passed through the cooling region, in which the work is cooled to a temperature at which it will not become oxidised on exposure to ambient

air. The required atmosphere is typically generated in, for example, an exothermic or endothermic gas generator or an ammonia cracker. The atmosphere is supplied to the thermal treatment region and expands to fill the whole gas space in the furnace. Since the atmosphere is particularly flammable, it is generally necessary to burn the atmosphere both the furnace entrance, and furnace outlet. There is thus a bi-directional flow regimen in the furnace with gas diverging in both directions, from the thermal treatment zone.

It is necessary to supply gas to the furnace at a sufficient rate to maintain a positive pressure therein. Otherwise, there will be a substantial flow of air into the furnace through the inlet or the outlet with an attendant risk of oxidising conditions being created in the furnace. It has therefore been the practice to supply to the furnace at a rate well in excess of that theoretically required to provide the necessary reducing or non-oxidising conditions in the thermal treatment region.

It is an aim of the present invention to provide a method of heat treatment which is able to ameliorate the aforementioned drawbacks to the current practice described in the preceding paragraph.

According to the present invention, there is provided a method of heat treating metal in a continuous furnace having in sequence an entrance, a thermal treatment region, a cooling region, and an exit comprising the steps of substantially preventing ingress of air into the furnace through the entrance (if required) and the exit; introducing non-reactive gas (as hereinafter defined) and reducing gas into the furnace at chosen locations; creating a gas flow regimen within the furnace to provide non-oxidising or reducing conditions substantially throughout the furnace and, if desired, atmospheres of different compositions in the thermal treatment and cooling regions, and passing the metal through the furnace from the entrance to the exit.

By the term "non-reactive gas" as used herein, it is meant a gas which is non-reactive towards other constituents of the atmosphere and the work or metal being heat treated. Generally, nitrogen is used as the non-reactive gas, though, in certain instances, it may be desirable to use argon as an alternative if nitrogen has any deleterious effect on the metal being heat treated.

The term 'heat treating metal' as used herein includes annealing (including spheroidising), sintering (e.g. of powders including non-metallic powders) brazing, hardening and malleabilising. The method according to the invention is particularly suited for use in annealing and sintering.

The method according to the invention is suitable for use with both horizontal continuous furnaces (i.e. furnaces through which the work travels, generally horizontally) and vertical furnaces (furnaces through which the work passes vertically). Examples of horizontal continuous furnaces include continuous strip wire furnaces, mesh belt furnaces, roller hearth furnaces and pusher furnaces.

Typically, non-reactive gas and reducing gas are introduced directly into the thermal treatment region of a horizontal furnace. Alternatively, they can be introduced into the furnace at a location in the cooling region, for example, at one or more locations near to the thermal treatment region, but alternatively or additionally at one or more locations remote from the thermal treatment region, the flow being such that a substantial portion of the reducing gas flows into the thermal treatment region. Since the non-reactive gas and the reducing gas are typically introduced into the furnace at about ambient temperature, while the thermal treatment region may be at temperature of up to 1100 degrees C depending on the kind of heat treatment to be performed, there is a substantial expansion of the gases in the thermal treatment region. Accordingly, there is a tendency for gas to flow out of this region both in the direction of the inlet to the furnace and in the direction of the cooling region. In a horizontal furnace we prefer to create a flow regimen in which the flow of gas out of the thermal treatment region at one of its ends is substantially greater than the flow of gas out of the region at its other end. We also prefer in such a furnace to ensure that the gas mixture leaving the furnace at both ends is non-flammable

while having to resort to burning - off flammable gas near only one end. Typically the end near which gas is burned off is the entrance to the furnace, and flow of gas out of the thermal treatment region to the cooling region is impeded. Means providing a physical obstruction to the gas flow may be employed in the cooling region of the furnace to help impede flow of gas out of the cooling region through the furnace exit. Preferably, non-reactive gas is supplied to the cooling region at one or more locations, typically with a component of velocity horizontally in the direction of the thermal treatment region, so as further to impede the flow of gases out of the thermal treatment region through the cooling region. By this means it is possible to reduce by a substantial margin the amount of gas that flows from the thermal treatment region into parts of the cooling region remote from the thermal treatment region and therefore the total rate of supplying reactive gas to the thermal treatment region may be reduced.

Since it is possible by these means to reduce substantially the amount of reducing gas which reaches the exit of the furnace, it is generally not necessary to burn-off gas at the exit of the furnace. Accordingly, any flue or the like at or rear the exit is desirably sealed to prevent air from flowing into the furnace therethrough.

It is desirable to introduce non-reactive gas into a horizontal furnace at one or more locations at or near the outlet (i.e. furnace exit) if desired, with a component of velocity in the direction of the outlet or flow restriction means) so as to provide a positive flow of gas through the outlet which is effective to prevent or substantially limit the ingress of air into the furnace through its exit. Typically, such non-reactive gas may also perform the above-mentioned function of reducing the proportion of reactive gas in the atmosphere leaving the exit of the furnace.

Preferably, in order to help impede the ingress of air into the furnace through its outlet, flow restriction means are provided there so as to impede the flow of gas into the furnace without preventing the metal being treated from passing out of the furnace. Typically, said means providing a physical obstruction to the flow of gas out of the cooling region are also

used to help impede in leakage of gas into the furnace through the exit. A suitable flow restriction means comprises one or more curtains comprising a multitude of generally vertically depending fibres or filaments which when not displaced obturate substantially the whole cross-sectional area of the furnace at or near the outlet but whose lower ends can be displaced laterally by metal being passed through the furnace to allow the metal to pass through the or each curtain. A combination of such flow restriction means and means for introducing non-restrive gas into the furnace at or near to the flow restriction means is generally particularly effective in substantially preventing ingress of air into the furnace through the outlet.

In preferred examples of the method according to the present invention a part of the cooling region near to the furnace exit has spaced-apart partitions and/or curtains or the like defining at least one chamber into which nitrogen or other non-reactive gas is introduced, the partitions being arranged to permit metal being treated to pass through the chamber or chambers.

Such a technique may be employed generally in heat treatment furnaces to help reduce the total consumption of gas. For example, in sintering, it is known to employ a pre-heat region intermediate the sintering (or thermal treatment region) and the furnace entrance. Lubricant and the like are oxidised in the pre-heat region. Thus, a limited flow of air into the furnace through its entrance may be tolerated to help create the necessary oxidising conditions. Accordingly, the invention also provides a method of heat treating metal in a continuous furnace having, in sequence, an entrance, a thermal treatment region, a cooling region and an exit, and also having at or near to one end thereof spaced-apart partitions and/or curtains (or the like) defining at least one chamber adapted to permit metal being treated to pass therethrough, said method comprising the steps of introducing a suitable gas or gases into the thermal treatment region to provide a suitable atmosphere for the treatment, supplying non-reactive gas to the chamber or chambers so as substantially to prevent ingress of air from outside the furnace through the chamber or chambers into a part of the furnace intermediate the chamber or chambers, and the thermal treatment region, and passing metal through the furnace from the entrance to the exit.

The non-reactive gas is preferably introduced directly into the chamber or chambers.

The introduction of non-reactive gas into the chamber or chambers is preferably at such a rate and the physical obstruction that the partitions present to the flow of gas is preferably such that:

$$Pc > Pu \quad \text{and} \quad Pu > Pa$$

where: Pc is the pressure in the chamber or chambers

Pu is the pressure in the furnace atmosphere at a region proximate said chamber or chambers and intermediate said chamber or chambers and the thermal treatment region, and

Pa is atmospheric pressure.

More preferably, in a horizontal furnace there are at least two chambers and

$$Pc > Pu > Pt > Pa$$

where: Pc is the pressure in the chamber nearest the thermal treatment region; Pu and Pa are as before, and Pt is the pressure in the thermal treatment region.

Where the chamber or chambers are in the cooling region near the exit end of the furnace and with the pressure in the chamber or chambers greater than atmospheric pressure the tendency for air to flow or seep into the cooling region of the furnace through the furnace exit is reduced. With the pressure in the chamber or chambers greater than the pressure in the rest of the cooling region and the pressure in the thermal treatment region, the creation of the desired flow regimen in the furnace, with a non-flammable gas mixture leaving the furnace exit, is facilitated while enabling the total requirements for non-reactive and reducing gas to be reduced.

Where two or more such chambers are employed, these chambers will typically intercommunicate with and be at substantially the same pressure as one another.

Preferably there are at least two, and typically three or more chambers, each supplied directly with non-reactive gas. With such an arrangement of chambers, in particular, it is possible, if desired, to maintain a relatively high hydrogen (or other reactive gas) concentration (e.g. 50% by volume or more) in the part of the cooling region intermediate the thermal treatment region and the chambers while maintaining progressively lower hydrogen (or reactive gas) concentrations in successive chambers from the innermost to the outermost (the concentratoin of hydrogen in the outermost chamber being such that the atmosphere therein is non-flammable). Having a high hydrogen concentration in most of the cooling region assists in cooling the metal owing to the relatively high specific heat of hydrogen. Such a high hydrogen concentration may be desirable if the furnace is required to treat a particularly large mass of metal per unit time, but on other occasions may be unnecessary, and, instead, it may be desirable to confine the highest hydrogen concentrations to the thermal treatment region by introducing most of the hydrogen into the thermal treatment region directly, or into a part of the cooling region near to the thermal treatment region.

The partitions are typically hinged or pivoted to suitable supports are or near the roof of the furnace. If the metal being treated is in the form of an elongate strip, each partition may take the form of a flap adapted to make a substantially fluid-tight seal or engagement with the metal being treated and the sides of the furnace. If the metal being treated comprises more bulky items (e.g. gears) each partition may comprise a row of members of 'fingers' pivotally mounted or hinged at the top of the furnace and extending downwardly to the work-carrying surface of the furnace, with adjacent 'fingers' overlapping. Such an arrangement offers a physical obstruction to the flow of gas while permitting the metal to be treated to pass therethrough. Various materials may be employed to form the partitions. For example, they mey be of steel or ceramic material or may be of a suitable composite or laminate.

The reducing gas may be hydrogen, typically supplied from a container of commercially pure hydrogen under pressure, or an ammonia cracker, or may be a hydrocarbon such as methane or propane. The reducing gas may alternatively be a mixture of carbon monoxide and hydrogen generated _in situ_ by thermal decomposition of a volatile organic compound, such as

methanol. At temperatures above 700 degrees C one mole of methanol decomposes to yield one mole of carbon monoxide and two moles of hydrogen. Methanol is a preferred source of hydrogen if the work to be heat treated is oily. If there is grease on the work it may also be advantageous to introduce water into the treatment region or a pre-heat region to combat deposition of soot on the work. This may be done by passing non-reactive gas through a humidifier before it enters the treatment region. It is important that the metal itself is not oxidised and thus non-oxidising or reducing conditions (so far as the metal is concerned) are maintained substantially throughout the furnace.

If desired, non-reactive gas may be introduced into the furnace at one or more locations intermediate the thermal region and the inlet, preferably with a horizontal component of velocity in the direction of the inlet, so as to help prevent or limit the ingress of air into the furnace through the inlet. A baffle or baffles, or arrangement of chamber with supply of non-reactive gas thereto such as may be employed in the cooling region may be used at the inlet or entry end of the furnace. Typically, the reducing gas in the gas mixture passing through the inlet is burnt off as in conventional operation of a continuous heat treatment furnace.

The composition of the atmosphere in the thermal treatment region of the furnace will b chosen inter alia in accordance with the treatment to be performed, the composition of the metal to be treated, the dew point of the fluids used to form the atmosphere, whether or not the metal to be treated comes into the furnace carrying oil on its surface and the effectiveness of the measure adopted to limit or exclude air from the furnace.

By substantially limiting the ingress of air into the furnace, it is generally possible, if desired, to work with lower average concentrations of reducing agent in the furnace atmosphere for a given treatment than would be possible in conventional operation of the furnace without substantially reducing the concentration of reducing gas that obtains in the thermal treatment region. Furthermore, by using supplies of commercially pure hydrogen and nitrogen rather than say cracked ammonia, it is possible to reduce the dew point of the atmosphere in the furnace, and thus work with lower levels of reducing gas than when, say, cracked ammonia is used as a source of reducing gas. By inhibiting the flow of reducing

gas from the thermal treatment region to the cooling region, it is possible to reduce the rate at which reducing gas needs to be supplied to the thermal treatment region. Thus, it is possible in many instances to make considerable reductions (eg by more than 50%) in the rate of supplying gas to conventional horizontal treatment furnaces and thereby reduce the cost of operating them.

Typical atmospheres that can be created in the thermal treatment region for various treatments of various materials are set out in tables 1 and 2 below (though in some instances higher hydrogen concentrations may be employed).

In a method according to the invention there is not a uniform atmosphere in the thermal treatment and cooling regions of the furnace. Typically, the atmosphere substantially throughout the cooling region contains a substantially lower proportion of reducing gas such as hydrogen than the atmosphere in the termal treatment region. In some instances, however, relatively high hydrogen (or other reducing gas) concentrations in a major portion of the cooling region may be required (eg for efficient cooling or to enable an increased throughput of work to be dealt with) and indeed the reducing gas concentration may be higher than or substantially the same as that in the termal treatment region. In such instances, there will be substantially lower hydrogen (or other non-reducing gas) concentrations in the said chamber or chambers. Thus even in such instances the requirement for a non-uniform atmosphere in the thermal treatment and cooling regions of the furnace is met.

TABLE 1

Material/Process	Atmosphere Composition %					
Annealing	CH_4	C_3H_8	H_2	Cracked NH_3	CH_3OH	N_2
Alloy steels	2-4	-	-	-	-	Bal
Mild steel	-	-	2-4	-	-	Bal
Mild steel	-	-	-	3-7	-	Bal
Mild steel/ carbon steel	2-4	-	-	-	-	Bal
Mild steel/ carbon steel	-	0.5-1	-	-	-	Bal
Mild steel/ carbon steel	-	-	-	-	15-50	Bal

TABLE 2

Material/Process	Treatment Temperature	Atmosphere Options				
Annealing	°C	N_2%	CH_4%	H_2%	CH_3OH%	(Cracked Gas)
Copper	350-650	-	-	-		-
		99	-	1		-
		98	2	-		-
Bronze	480-680	95	-	5		-
Nickel silver	540-820	95	-	5		-
		85	-	-		15
Brass	350-750	95	-	5		-
		75	-	25		-
		80	-	-		20
Nickel alloys	760-1100	96	4	-		-
		96	-	4		-
High chromium alloys	1100	95	-	5		-
		75	-	25		-
Silver alloys	850-650	96	-	4		-
Sintering	800-1200	95	-	5		-
		80-95	-	5		5-20
Brazing	800-1200	95	-	5		-
		75	-	25		-
		85	-	-		15
Hardening		80-90	-	-		10-20

The method according to the invention may also be employed in the heat treatment of ferrous and non-ferrous metals in continuous vertical heat treatment furnaces. An example of such a furnace is a vertical strip annealing furnace which comprises a generally vertical rising leg having an inlet at its bottom and a generally vertical downward leg having an outlet at its bottom, the two legs intercommunicating at the top. Guide means are typically located within the furnace for guiding the part of the strip from the inlet to the outlet. Typically, in the down leg, a thermal treatment region is provided near the top thereof, and a cooling region therebelow. Typically, in operating such a furnace in accordance with the invention, non-reactive gas such as nitrogen is supplied to the up leg at a plurality spaced apart locations and reducing gas, preferably comprising hydrogen, is preferably introduced into the down leg in one or both of the cooling region or the thermal treatment region. Preferably, one flow of non-reactive gas is introduced into the furnace, proximate to the inlet thereof and another flow proximate to the outlet thereof so as to inhibit or prevent the flow of air into the furnace therethrough. If desired, the aforesaid chamber or chambers may be employed at the exit (or outlet) end of the furnace, and, also, if desired, an analogous arrangement at the inlet or entry end. In a vertical strip annealing furnace, as described, above the partitions may each comprise a generally horizontal plate with an aperture formed therethrough to guide the strip. By substantially inhibiting such a flow of air into the furnace it is possible to make a reduction in the amount of hydrogen employed in the atmosphere in the thermal treatment region. It is, however, necessary to ensure that adequate cooling takes place in the cooling region. Accordingly, in many such furnaces, we believe that it is advantageous to maintain a relatively high concentration of hydrogen in the cooling region in view of its relatively high thermal conductivity (in comparison with nitrogen).

Thus, hydrogen or cracked ammonia may be introduced solely into the cooling region to create an atmosphere containing more hydrogen than that required in the thermal treatment region. Owing to its relatively low density in comparison with nitrogen, or argon, there will be a considerable upward drift of hydrogen from the cooling region into the termal treatment region and thus the necessary atmosphere therein may be provided.

Nitrogen or other non-reactive gas is preferably supplied to the rising leg of the furnace so as to limit substantially or prevent a flow of hydrogen from the down leg of the furnace to the rising leg. By this means, the rate at which hydrogen need be supplied to the furnace may be reduced in comparison with conventional practice.

The method according to the invention will be described in the ensuing examples with reference to the accompanying drawings, in which:

Figure 1 is a schematic drawing of a mesh belt furnace adapted to perform the method according to the invention;

Figure 2 is a schematic diagram illustrating flow circuits for supplying nitrogen and methanol to the furnace shown in Figure 1;

Figure 3 is a graph showing a typical example of how a composition of the atmosphere in the furnace there is along its length;

Figure 4 is a schematic drawing of a continuous sintering furnace;

Figure 5 is a schematic drawing illustrating a vertical furnace for the bright annealing of the stainless steel;

Figure 6 is a schematic drawing of another mesh belt furnace adapted to perform the method according to the invention;

Figure 7 is a schematic diagram depicting the arrangement of chambers from part of the cooling region of the furnace shown in Figure 6.

This example relates to the annealing of ferrous metal parts in a standard Birlec 18" mesh belt furnace.

Referring to Figure 1 of the accompanying drawings, the mesh belt furnace, indicated by the reference 2, has an inlet 4 and an outlet 6 for the work to be annealed. The furnace has a thermal treatment region 8, located near to the inlet 4, and a cooling region 10, intermediate the outlet 6 and the thermal treatment region 8. The thermal treatment region 8 is heated

by means of "glow-bar" heating elements (not shown).

Work to be annealed is fed on to an endless mesh belt 11 which is driven around an endless path extending through the furnace 2 from the inlet 4 to the outlet 6, the belt 11 being mounted on rollers 12, at lease one of which is driven by means of a motor (not shown). In operation, work to be annealed is loaded on to the belt just in advance of the inlet 4 and is conducted through the furnace at a chosen rate until it passes through the outlet 6 where it is lifted off the belt.

Positioned underneath the mesh belt 11 in the thermal treatment region 8 are two inlets 14 and 16 through which gas can be supplied to the treatment region 8. Inlets 14 and 16 form part of the furnace before it was adapted to operate the method according to the invention.

Extending downwardly from the top of the furnace to the thermal treatment region are two coaxial nitrogen/methanol injectors 18 and 20. The injector 18 comprises an outer pipe 22 for nitrogen and an inner 26 for methanol coaxial with the pipe 22. The pipe 26 terminates within the pipe 22, a short distance above its outlet. The injector 20 is substantially identical to the injector 18 having an outer nitrogen pipe 24, and an inner methanol pipe 28. The injectors 18 and 20 are operable such that droplets of methanol become entrained in the nitrogen and vaporise before impinging upon the work to be annealed.

A directional nitrogen injector 30 comprising a pipe having perforations or apertures pointing at an angle of 45 to the vertical in the direction of the outlet 6 extends into the cooling region 10 from the roof of the furnace 2. The injector 30's position in the cooling region is relatively near to the outlet 6 of the furnace. Positioned intermediate injector 30 and the outlet 6 are four rows of curtains 34 depending from the roof furnace 2 and ending a sufficient distance above the mesh belt 10 to enable work to pass therethrough. Typically, the curtains each comprise a multitude of closely grouped together , generally vertically depending, glass fibres which when the curtain is "closed" substantially obturate the outlet of the furnace, but which may be parted by metal passing through the furnace thereby permitting the metal to pass out of the furnace.

Extending downwardly into an upper part of the cooling region 10 is a directional nitrogen injector 32 having apertures or perforations pointing at an angle of 45^{o} to the vertical in the direction of the thermal treatment region 8. The injector 32 is positioned intermediate the injector 30 and the thermal treatment regions.

In operation of the furnace 2, nitrogen is typically introduced into the cooling region 10 from the injectors 30 and 32 so as to purge air from the furnace. The means for heating the thermal treatment region 8 are then activated so as to raise the temperature therein to a chosen treatment value. Nitrogen and methanol may then be introduced into the treatment region 8 so as to create a desired atmosphere therein. As the methanol, introduced as liquid, flows into the treatment region 8, so it vaporises with a considerable expansion in volume. Similarly, the nitrogen introduced into the treatment region 8 through the injectors 18 and 20 and through the inlets 14 and 16 is warmed from about ambient temperatures to the treatment temperature and also expands. The nitrogen introduced into the cooling region 10 through the injector 32 has a component of velocity in the direction of the thermal treatment region 8 and its flow is arranged to be sufficient so as to inhibit considerably the flow of expanding gases out of the thermal treatment region 8 into the cooling region 10. These gases thus flow largely in the direction of the inlet 4. They pass into a flue 38 where flammable constituents are burned off. A sliding plate 40 is provided for the purposes of adjusting the flow of such gas into the flue 38.

Generally, the flow of gases under the plate 40 will be sufficient to prevent ingress of substantial quantities of air into the furnace through the inlet 4. If desired, however, nitrogen may be introduced into the furnace intermediate the treatement region 8 and the inlet 4 through a nozzle or injector (now shown) having one or more outlets pointing towards inlet 4. The additional nitrogen flow thus created helps prevent ingress of air through the inlet 4.

The arrangement of the injector 30 and the curtains 34 substantially limits the ingress of air into the furnace through the outlet 6. If there is any flue associated with the outlet 6, similar to the flue 38, for burning-off inflammable gas, this should be sealed to prevent air flowing into the furnace therethrough.

Suitable nitrogen methanol supply equipment for the use with the furnace shown in Figure 1 is illustrated in Figure 2. The equipment includes a nitrogen supply pipeline 50 communicating with a source (not shown) of commercially pure nitrogen. Typically, this source is a vacuum-insulated vessel containing nitrogen in its liquid state, the vessel being fitted with a vaporiser so as to vaporise liquid nitrogen. The supply equipment also includes a pipeline 52 communicating with a vessel (not shown) containing liquid methanol. The methanol may be supplied to the pipeline 52 by means of a pump or under the pressure of nitrogen supplied to the ullage space of the aforesaid vessel containing methanol.

An isolating or shut-off value 54 is positioned in the nitrogen pipeline 50 and is operable to isolate the inlet 14 and 16, the injector 18, 20, 30 and 32 from the source of nitrogen. A pressure regulator 56 is located downstream, of the valve 54 in the pipeline 50 and is operable to adjust the supply in pressure of nitrogen to pipes 58, 60, 62 and 64, communicating with the pipeline 50 downstream of the regulator 56. A pipe 58 communicates with two subsidiary pipes 72 and 74, serving the injectors 30 and 32 respectively. The pipe 60 communicates with the inlets 14 and 16, the pipe 62 with the nitrogen pipe 22 of the injector and the pipe 64 connects the source of nitrogen to the pipe 24 of the injector 20. Flow control valves 66 are located in each pipe 60, 62 and 64. In each such pipe there is provided a flow meter 68 downstream of the valve 66.

A flow meter is also provided in the pipe 58. In each of the pipes 60, 62 and 64, there is a pressure regulator 70 located downstream of the respective flow meter 68.

The pipe 58 ends in the union of the pipes 72 and 74 and flow control valves 76 and 78 are provided in the pipes 72 and 74 respectively. The apparatus shown in Figure 2 has means for humidifying nitrogen supplied to the injector 20. This means comprises a drum 82 containing water having an inlet 80 which is submerged beneath the water and which communicates with the pipeline 64 downstream of the valve 70. The drum 82 has an outlet communicating with a pipe 86 leading to the nitrogen pipe 28 of the injector 20. If it is desired that the nitrogen flowing through the pipeline 64 downstream of the union of the latter with the inlet 80 should be dry the valve 84 is opened and all the nitrogen in the pipe 64 flows through the valve 84 and thence into the pipe 86, whereas when the valve 84 is closed, all the nitrogen entering the pipeline 64 flows through the drum 82. The purpose of the humidifier will be described below.

The methanol pipeline 52 has first shut off or isolating valve 88, disposed therein. Downstream of the methanol pipe 88 is a filter 90 to remove any suspended solids from the methanol. A pipeline 96 communicates with the pipeline 52 downstream of filter 90, the pipeline 96 communicating with the methanol pipe 26 of the injector 18. A flow control valve 98 is provided in pipe 96, and downstream of the valve 98 is a flow meter 100. Downstream of the union of the pipeline 96 with the pipeline 52, is a flow control valve 92, and downstream of that a flow meter 94. Downstream of the flow meter 94, the pipeline 52 communicates with the methanol pipe 28 of the injector 20.

Before adaptation by fitting the injectors 18, 20, 30 and 32, and the curtains 34, and connecting the inlets 14 and 16 to the nitrogen (as well as shutting off any flue at the outlet end of the furnace), the furnace 2 was operated by supplying 2,000 standard cubic feet per hour of rich exothermically generated gas to the thermal treatment region 8 through the inlets 14 and 16. The resulting flammable gas mixture was burned off at both ends of the furnace. It was found that bright work could be obtained by operating the method according to the invention when the furnace was

adapted as shown in Figures 1 and 2. In a typicaly example, universal joint forgings were annealed at 900°C in the thermal treatment region 8 and then cooled to near ambient temperature in the cooling region 10. The supply of nitrogen and methanol to the respective fluid inlets and injectors was as follows:-

Inlets 14 and 16: 220 standard cubic feet per hour of nitrogen.
Injectors 18 an 20: 440 standard cubic feet per hour of nitrogen and 2 litres per hour of methanol.
Injector 30: 100 standard cubic feet per hour of nitrogen.
Injector 32: 100 standard cubic feet per hour of nitrogen.

The flow was equally divided between the injectors 18 and 20.
One litre of methanol per hour decomposes at the working temperature to yield 20 standard cubic feet per hour of carbon monoxide and 40 standard cubic feet per hour of hydrogen. It can thus be seen that the total flow of gas into the furnace amounted to 1,000 standard cubic feet per hour, that is half the flow rate with exothermically generated gas.

Parts from large castings to small pressings were treated in the furnace with the nitrogen and methonal supplied to the furnace of the rates described above at the maximum thermal treatment region temperatures in the range 720 to 1060°C.

Figure 3 illustrates the variation in the composition of the furnace atmosphere with the location in the furnace when the treatment region 8 is operated at 970°C. It can be seen that the concentration of hydrogen in the atmosphere in the treatment region 8 was in the order of 7%, but it decreased progressively along the cooling region 10 in the direction of the outlet 6, falling to below 1% before the outlet 6 is reached. Similarly, the carbon monoxide level falls from between 3.5% and 4% in the thermal treatment region to below 1% at the end of the cooling region 10 remote from the thermal treatment region 8. There is a corresponding fall in carbon dioxide concentration from about 0.4% in the thermal treatment region 8 to below 0.1% at the end of the cooling region 10 remote from the thermal treatment region 8, (all percentages are by volume). Thus the gas leaving the furnace through the outlet 6 was substantially free of flammable reducing gas.

In this example, methonal was chosen as the source of reducing gas in view of the oily condition of some of the work to be treated. This gave an atmosphere having a relatively high dew point in the thermal treatment zone eliminating the position on the heating elements caused by entrained oil when using a nitrogen methane or nitrogen hydrogen atmosphere. Nonetheless, owing to the supply of nitrogen to the cooling region 10, a substantially non-reactive atmosphere is created there under the prevailing conditions, thus enabling a bright finish to the work to be obtained.

The injectors 18 and 20 were designed with the pipes 22 and 24 closed at their respective bottoms but with orifices in their sides. Thus, methanol leaving the pipes 26 and 28 struck the closed ends of the pipes 22 and 24, breaking into droplets which were carried by the nitrogen through orifices in the pipes 22 and 24 into the treatment region 8. This prevented relatively fast moving methanol jets striking the heating elements of other parts of the furnace before vaporising. Had this even taken place, there would have been a tendency for carbon to have been deposited on the work.

It was also found that at the levels of hydrogen and carbon monoxide employed in the thermal treatment region 8, it was generally desirable to direct nitrogen from the injector 30 at the curtains 34 in order to ensure that ingress of air into the furnace was not so great as to depress the dew point of the atmosphere in the cooling region 10 to a level at which inferior quality work was produced.

When particularly oily or greasy work was encountered, the humidifier drum 82 was used to add water vapour to the atmosphere and thereby help prevent soot formation on the work and the furnace structure.

A flame curtain was provided under the mesh belt 10 at the inlet end of the furnace when treating large pressings. The purpose of this was to consume oxygen in trapped air from the underside of the pressings.

Example 2

This example relates to the sintering of bronze on to a steel backing in a suitable continuous sintering furnace as illustrated in Figure 4.

Referring to Figure 4, a continuous furnace 200 has an inlet 202 for work to be sintered a thermal treatment region 204 having means (not shown) for raising it to a treatment temperature, a region 206 intermediate the inlet 202 and the thermal treatment region 204, an outlet 208 for work, and a cooling region 210 intermediate the thermal treatment region 204 and the outlet 208. Located in the cooling region 210 near the thermal treatment region 204, is an inlet pipe which is used for conveying to the region 204 a gas mixture suitable for providing the required atmosphere in the region 204. This inlet 212 is part of the conventional fittings of the furnace. In addition to the inlet 212 eight injectors 214 terminate in the cooling region 210, each injector being associated with its own nitrogen supply pipeline 216 in which are disposed a flow control valve 218 and a calibrated orifice 220 downstream of the flow control valve 218.

The pipes are all connected to a common pipeline 222 for the supply of nitrogen.

Located near to the outlet 208 is a nitrogen distribution pipe 224 terminating in the furnace. The orientation of the distribution pipe 224 is adjustable so as to enable the direction at which gas issues therefrom to be varied. It is preferably set such that there is a substantial component of velocity in the direction of the outlet. Typically, the distributor pipe 224 has outlet orifices whose axes extend at an angle of 45° to the vertical.

Curtains 226 are positioned in the furnace between the injector 224 and the outlet 208.

The array of curtains 226 is analogue to that described with reference to Figure 1 of the accompanying drawings.

The distribution pipe 224 has its own nitrogen supply pipe 228 in which is disposed a flow control valve 230 upstream of a calibrated orifice 232. The pipe 228 is connected tothe pipeline 222.

The cooling region 210 is typically cooled by an arrangement of water jackets 234.

Nitrogen may also be supplied to the region 206 of the furnace 200 through a distributor pipe 238 that is analogous to the distribution pipe 224. The pipe 238 is positioned such that gas issuing from it has a substantial component of velocity in the direction of the inlet 202. Typically, the arrangement of the pipe is such that gas leaves the pipe at an angle of 45° to the vertical. The pipe 238 is associated with pipe 240 having a calibrated orifice 242 disposed therein and a flow control valve 244 upstream thereof.

The gas inlet 212 is connected to a gas mixing panel 246 which is in turn connected to a source of nitrogen (not shown), and a source of cracked ammonia. At its inlet and outlet ends, the furnace is provided as a standard fitting with inlet pipes 250 for gas. These pipes are sealed off. Also at the inlet and outlet ends of the furnace are flues 252. The flue at the outlet end of the furnace is sealed.

The operation of the furnace shown in Figure 4 is substantially similar to that shown in Figure 1. Work to be sintered is advanced through the furnace 200 by means (not shown). A chosen mixture of nitrogen and cracked ammonia is introduced to the thermal treatment region 204 of the furnace from the inlet 212 located in the cooling region 210. The injectors 214 are used to introduce nitrogen at spaced apart locations in the cooling region 210 so as to create within the cooling region a nitrogen flow that helps to prevent free flow of gas from the inlet 212 and the thermal treatment region 204 in the direction of the outlet 208. It is to be appreciated that the curtains 226 act as an impedence to the flow of gas out of the furnace 200 through the outlet 208, and also the nitrogen directed thereat from the distributor pipe 224 to help to prevent the ingress of air into the furnace through the outlet 208. Similarly, the nitrogen directed to the inlet 202 from the distributor pipe 238 helps to prevent ingress of air into the furnace through the inlet.

Nitrogen and cracked ammonia entering the thermal treatment region 204 tend to expand and by virture of the introduction of nitrogen through the injector 214 into the cooling region 210 tends to flow out of the thermal treatment region 204 through region 206, and then into the flue 252 where its content of inflammable gas (hydrogen) is burned-off. It is to be appreciated that the effect of the production of nitrogen into the cooling

zone 210 through the injectors 214 and the distributor 224 renders negligible the amount of inflammable gas in the gas leaving the furnace through the outlet 208.

Typically, in the sintering of powdered bronze on to a steel backing, an atmosphere containing from 20 to 30% by volume of hydrogen and a balance of nitrogen is conventionally used, this atmosphere being supplied to the furnace through the inlet 212 and the sealed inlets 250. We believe that the hydrogen rquirements can be substantially reduced and that the nitrogen flow to each of the injectors 214 and the distributor 224 may typically amount to some 400 to 500 standard cubic feet per hour, the nitrogen flow being evenly divided between the 8 injectors and the distributor pipe.

The gas mixture supplied to the pipe 212 and hence to the thermal treatment region may typically be a mixture of 50 standard cubic feet per hour of cracked ammonia (25% nitrogen 75% hydrogen) and up to 300 standard cubic feet per hour of nitrogen. Nitrogen is preferably supplied to the distributor 238 at a rate of 150 to 200 standard cubic feet per hour.

Example 3

This example relates to the bright annealing of stainless steel strip in a vertical annealing furnace.

Referring to Figure 5 of te drawings, a vertical stainless steel bright annealing furnace 300 comprises an up-leg 302 and a down-leg 304 joined together at the top by a connecting section 306. At the bottom of the up-leg 302 there is an inlet 308 with a strip. At the bottom of the down-leg there is an outlet 310 for strip. The inlet 308 and outlet 310 are relatively restricted in comparison with the general cross sectional area of the legs. Located near to the inlet 308 is a baffle 312 which restricts flow of gas from above the baffle 312 in the direction of the inlet 308. A similar baffle is located near the outlet 310 so as to restrict flow of gas from thereabove through the outlet 310. Guide rolls 314 are located near the inlet 308 and outlet 310 and in the section 306 so as to feed the strip continuously through the furnace.

At an upper region of the down-leg 304 is located a thermal treatment

region 320. This region is surrounded by radiant heating elements 322 outside the down-leg 304. A cooling region 318 is located beneath the thermal treatment region 320 in the down-leg 304. The cooling region 318 is provided with a fan (not shown) for circulating gas within that region.

Gas inlets to the legs of the furnace are provided at several spaced apart locations with the up-leg 302 and the down-leg 304. There is a first nitrogen inlet 324 to provide a flow of nitrogen into the up-leg at a region near to the inlet 308 (intermediate the inlet 308 and its baffle 312) so as to prevent the ingress of air into the furnace 308.

There is a plurality of inlets 326 all communicating with the up-leg of the furnace so as to provide an atmosphre consisting substantially of nitrogen in the up-leg. There is a third inlet 328 for nitrogen communicating with a part of the down leg 304 near to the outlet 310 and intermediate the outlet 310 and its baffle 312. This enables nitrogen to be supplied to the outlet so as to prevent substantially all ingress of air to the furnace through the outlet 310. There is a plurality of inlets 330 for hydrogen or cracked ammonia (three parts hydrgoen to one part nitrogen) to the cooling region 318. The relative rates of supplying nitrogen and hydrgoen (or cracked ammonia) to the furnace are chosen so as to provide suitable conditions for the bright annealing of stainless steel in the cooling region and the thermal treatment region. By excluding or substantially excluding air from the furnace, substantially less hydrogen or cracked ammonia than would otherwise be needed is employed. Furthermore, by arranging the nitrogen flow into the upper leg 302 to be sufficient to exclude the flow of hydrogen from the down-leg 304 into the upper leg 302, the rate of supplying hydrogen to the furnace may be limited to that required to provide suitable atmospheres in the cooling region and the thermal treatment region. It is therefore possible to use considerably less hydrogen in the atmosphere than is achieved in conventional treatment using cracked ammonia. There will be a flow of nitrogen from the up-leg to the down-leg 304. Thus the atmosphere in both the cooling region 318 and the thermal treatment region 320 contains both nitrogen and hydrogen that in the cooling region contains the greater proportion of hydrogen.

Typically, in the conventional bright annealing of the stainless steel in the furnace using cracked ammonia, some 2,600 cubic feet per hour of cracked ammonia were used, whereas total gas flows in this example can be reduced to the order of 1,700 to 1,800 cubic feet per hour.

In order to provide adequate cooling in the cooling region 318 it is typically desirable to use an atmosphere having a relatively high concentration of hydrogen in comparison with that used in the thermal treatment region. This is because hydrogen has a high thermal conductivity in comparison with nitrogen. If the source of hydrogen is cracked ammonia, the hydrogen concentration in the cooling region may be arranged to be 60 to 62% (dew point - 50^{o}C). Or, if the source of hydrogen is a cylinder of commercially pure hydrogen, 54 - 60% by volume hydrogen (dew point - 55^{o}C). However, in the thermal treatment region, the atmosphere may typically contain from 36 to 43% by volume of hydrogen if the source of hydrogen is cracked ammonia, and from 28 to 41 by volume of hydrogen if the source of hydrogen is a cylinder of compressed commercially pure hydrogen. Such atmosphere can be achieved by introducing nitrogen into the up-leg 302, through the inlets 324 and 326 at the rate of flow in the range of 800 to 1,000 cubic feet per hour, nitrogen into the down-leg 304 through the inlet 328 at a flow rate of 300 to 400 cubic feet per hour, and cracked ammonia at a flow rate of 400 to 450 cubic feet per hour (or hydrogen at a rate of 200 to 300 cubic feet per hour) into the cooling region 318 through the inlet 330. Owing to the upward migration of hydrogen as a result of its low density and passage of nitrogen from the up-leg 302 to the down-leg 304, the gas analyses set out in Table 3 below are typically produced.

The above results were obtained when annealing estimated stainless steel strip (300 series) at a temperature of 1050^{o}C. The precise amount of hydrogen required in the cooling region depends on the thickness of the strip. In general, the thicker the strip, the more hydrogen required in the cooling region. If desired, the furnace may be shut down for periods, e.g. for the weekend but still maintained in condition by supplying a gas mixture comprising 96% by volume of nitrogen and 4% by volume of hydrogen to the section 306 to establish such atmosphere throughout the furnace.

TABLE 3

POSITION IN FURNACE	SOURCE OF ATMOSPHERE N_2 - CRACKED AMMONIA			SOURCE OF ATMOSPHERE N_2 - COMMERCIALLY PURE H_2		
	% by vol N_2	% by vol H_2	dewpoint (^oC)	%by vol N_2	% by vol H_2	dewpoint (^oC)
Inlet 308	100	-		100	-	
Top of upleg 302	98-99.5	0.5-2		99-99.7	0.3-1	
Top section 306	58-65	35-42	-34	58-74	26-42	-36
Thermal treatment zone 320	57-64	36-43		59-72	28-41	
Cooling region 318	38-40	60-62	-50	40-46	54-60	-55
Outlet 310	62-67	33-38		67-50	20-33	

Example 4

This example relates to the bright annealing of ferrous or non-ferrous metal strip in an FHD mesh belt furnace.

Referring to Figure 6 of the drawings, a mesh belt (not shown) advances strip (or other metal to be treated) from the inlet or entry 602 to the furnace to the outlet or exit 604 from the furnace. The furnace has, in sequence, advancing from the entry 602 to the exit 604, an inlet region 606, a thermal treatment region 608, and a cooling region 610. At the end of the cooling region 610 remote from the thermal treatment region 608 are chambers 612, 614 and 616 defined by generally vertical partitions 618 that cooperate with the walls of the furnace to define the chambers. A sliding plate 619 is provided at the exit 604 and defines a further chamber 621 with the nearest of the partitions 618 thereto.

A flare-off means 620 is provided in communication with the top or roof of the inlet region 606 at a location intermediate a chamber 622 in the inlet region 606 and the thermal treatment region 608. The chamber 622 is defined between the walls of the furnace, a first sliding plate 626, included at an angle to vertical, at the entry 602 and a hinged plate 624 which may be raised or lowered to vary the size of the gap betwen the bottom edge of the plate 626 and the mesh belt (not shown).

The chambers 612, 614 and 616 each communicate with upper and lower nitrogen-supply plenum chambers 628 and 630, and the chamber 622 with analogous nitrogen-supply plenum chambers 632 and 634.

The furnace is also provided with a variable angle nitrogen injector 636 situated in the inlet region 606 of the furnace intermediate the plate 626 and the thermal treatment region 608. A nitrogen inlet 640 to the furnace is also provided at a location in the cooling region 610 near to the thermal treatment region. A variable angle hydrogen injector 638 is also provided in the cooling region outside but near to the chamber 612.

The arrangement of the chambers 612 614 and 616 is shown schematically in Figure 7.

The partitions 618 comprise steel plates or flaps each hinged to a support 642 depending from the roof 644 of the furnace. The floor 646 of the furnace and the roof 644 are formed with spaced-apart slots 648 therein to allow nitrogen to pass into each of the chambers 612, 614 and 616 from the chambers 628 and 630. The chambers 628 and 630 have nitrogen inlets 650 and 652 connectible to a source of nitrogen. Baffle plates 654 and 656 are provided in the chamber to block the direct path between the inlets 650 and 652 and the respective sets of slots 648. Thus, in operation, nitrogen flows around the baffles 654 and 656 and through the slots 648, typically providing a laminar flow of gas into the furnace. The partitions hang at an angle of about 10^{o} to the vertical (with their bottom edges nearer to the exit 604 than their top edges) so as to enable some of the nitrogen to be deflected thereby and thus be given a horizontal component of velocity in the direction of the exit.

The bottom edge of each partition 618 contacts the metal strip being heat treated as it is passed through the furnace. If desired, each partition 618 may be provided at its edges with sealing means (not shown) to prevent substantially all gas flow between the partition and the side walls of of the furnace. There is however intercommunication between the chambers over the top edge of the partitions and through the mesh belt 658 of the furnace but seals at such top edge can readily be provided, if desired. Indeed, in general the more limited the intercommunication between the chambers 612, 614 and 616, the greater is the obstruction to the flow of hydrogen and other gas out of the furnace through the exit end 604 thereof and to inflow or inleakage of air through the exit 604, and hence the less nitrogen required to meet the objectives of achieving a high hydrogen concentration in the cooling region 610 intermediate the chambers 612, 614 and 616 and the thermal treatment region 608 while obtaining a non-flammable atmosphere in the chamber 621 by the exit 604 and substantially no inleakage of air into the furnace through the exit 604.

The furnace shown in Figures 6 and 7 may be operated as follows.

Nitrogen is supplied to the chambers 628,630, 632 and 634 and this is effective to flush air out of the furnace. The thermal treatment region 608 of the furnace is raised to a treatment temperature by heating means (not shown) associated with the furnace. Hydrogen is then supplied to the furnace through the variable angle injector 638, typically orientated so as to direct gas downwards at an angle of 20^{o} to the vertical with a horizontal component of velocityy in the direction of the inlet end of the furnace. The hydrogen reacts with any residual air in the thermal treatment region and once substantially all such residual air has been removed, strip may be advanced continuously through the furnace to be annealed. For this process, the furnace is typically set up with the inlets 636 and 640 closed, and the plates 624, 626 and 619 in their lowermost positions.

Nitrogen passes into the chambers 612, 614 and 616 from the uppper and lower supply chambers 628 and 630. A pressure in the chambers 612, 614 and 616 in excess of atmospheric pressure is built up. Some nitrogen will thus flow from chamber 616 into the chamber 621 and out of the furnace through exit 604. Introduction of hydrogen into the cooling region from the injector 638 and flow of nitrogen from the chambers 616, 614 and 612 into the cooling region 610 provides a flow of a gas mixture comprising nitrogen and hydrogen into the thermal treatment region 608. This directional flow is caused partly by the obstruction to flow in the opposite direction presented by the partitions 618 and the gas pressure in the chambers 612, 614 and 616 and partly by burning flammable gas issuing from the thermal treatment region 608, such flammable gas being burned in the flare-off means 620. (The burning helps to induce a flow in the direction of the entry 602 to the furnace). As the gas flows or diffuses in the direction of the thermal treatment region so it is progressively warmed (by convection from the thermal treatment region). Such warming causes the ga to expand and thus tends to create a back pressure in the cooling region 610. Thus, the pressure in the cooling region 610 at a point near to the chamber 612 and intermediate the chamber 612 and the thermal treatment region 608 will be greater than atmospheric pressure and greater than the pressure in the thermal treatment region 608 itself, provided nitrogen is supplied at a suitable flow rate to the chambers 628 and 630.

It is to be appreciated that some hydrogen will diffuse through the

chambers 612, 614 and 616 in the opposite direction to that of the general direction of flow. The rates of introduction of nitrogen and hydrogen can be chosen so as to give a relatively high concentration of hydrogen in the cooling region 610 and the thermal treatment region 608 of the furnace, (e.g. over 50% by volume) while hydrogen diffusing through the chambers 612, 614 and 616 in the general direction of the exit 604 is progressively diluted by the nitrogen to yield a non-flammable gas mixture leaving the outlet of the furnace.

Owing to the pressure differention in the direction of net flow of gas through the furnace, most of the gas in the thermal treatment region 608 of the furnace passes out of this region in the direction of the furnace entrance 602, although some gas will diffuse into the cooling region 610. Flammable gas mixture is burned in the flare-off means 620 as aforementioned. Nitrogen supplied to the chamber 622 from the supply chambers 632 and 634 impedes flow of hydrogen past the burn-off zone and also helps to impede flow of air into the furnace through the entrance 602.

By keeping down the rate at which air enters the furnace it is possible to use less reducing gas than would otherwise be necessary to provide a non-oxidising atmosphere. Moreover, by providing a flow regimen with only one flare or burn-off outlet it is possible to keep down the total amount of gas employed in the furnace per unit time. We believe these advantages can be achieved without imparing the quality of the treatment given to the metal or work.

A summary of experimental results obtained when operating the thermal treatment region at a temperature of 800^{o}C is given in table 4. The concentration of hydrogen was measured by taking samples at different locations A to I in the furnaces and the samples were also employed to measure the oxygen potential of the atmosphere at the locations A to I.

The positions A to I are as follows:

A - in the chamber 622

B - in the inlet region 606 near to the flare-off means 620

C - in the thermal treatment region 608

D - in the thermal treatment region 608 but nearer to the cooling region 610 than is the position C

E - in the cooling region 610 is intermediate the thermal treatment region 608 and the chamber 612

F - in the chamber 612

G - in the chamber 614

H - in the chamber 616

I - in the chamber 621

Experiments Nos 1 and 2 show that relatively high concentrations of hydrogen can be obtained in the cooling and thermal treatment regions while ensuring that the gas leaving the furnace through the exit 604 is non-flammable. In experiment No 3, additional nitrogen was admitted into the furnace through the inlet 640. In consequence, the proportion of hydrogen in the thermal treatment region was substantially less than in Experiments Nos 1 and 2 while still obtaining a relatively high proportion of hydrogen in the cooling region. This demonstrates that a generally unidirectional flow regimen from the cooling region to the thermal treatment region was obtained.

Experiment Nos 4 and 5 show that of the nitrogen supplied to the chambers 612, 614 and 616 may all be introduced from the upper plenum chamber 628, and that of the nitrogen supplied to the chamber 622 all may be introduced thereto from the lower plenum chamber 634.

The chambers near the exit end of the furnace may be provided by means of a custom-built unit fitted to the exit end of the furnace, thereby extending the length of the furnace.

Example 5

The method according to the present invention may be operated on continuous

furnaces used for sintering and having a region in which oil and lubricant on the work being sintered is oxidised. Such region is intermediate the inlet of the furnace and the thermal treatment region. Typically, the sintering temperature in the thermal treatment region is 1100°C and the delubrication region is maintained at a temperature in the range 500 to 700°C. The furnace may be provided with chambers at its entry and exit ends in the manner shown in and described with reference to Figures 6 and 7. In such a furnace a suitable flow regiment may be created by burning-off gas only near the entry end with gas being supplied at the following rates. Nitrogen is supplied to the chambers at the end of the cooling region remote from the thermal treatment region at a rate of from 150 to 200 cubic feet per hour and at a similar rate to the chamber at the entry end of the furnace. Gas generated in an endothermic generator (typically including about 40% by volume of hydrogen) is passed into the cooling region at a location outside but near to the chambers in that region at a rate of 100 cubic feet per hour. Such endothermic gas is also introduced into the cooling region at a location near to the thermal treatment region at a rate of 250 cubic feet per hour and nitrogen is introduced into the same region at a rate of 350 to 400 cubic feet per hour. There is thus a flow of nitrogen and hydrogen in the general direction of the thermal treatment region, reducing conditions being maintained in both the cooling and thermal treatment regions. In order to provide conditions that are oxidising to oil and lubricant etc in the oxiding region, 200 cubic feet per hour of humidified nitrogen is admitted to the region of the furnace intermediate the thermal treatment region and the oxidising region. This addition of humidified nitrogen is made so as to oxidise lubricant etc on the work to be sintered without decarburising the work itself. Flammable gas mixture leaving the oxidising region is burnt-off, this step helps to induce a general flow of gas in the direction of the furnace entrance. Substantially less gas is required than when the furnace is operated conventionally with burn-off of flammable gas mixture at both its inlet and outlet ends.

TABLE IV

	Experiment No: 1	2	3	4	5
Flow rate of N_2 into chamber 632	90	90	70	0	0
Flow rate of N_2 into chamber 634	90	90	70	180	180
Flow rate of N_2 to injector 636	0	0	0	0	0
Flow rate of N_2 to inlet 640	0	0	40	0	0
Flow rate of N_2 to chamber 628	60	60	60	80	80
Flow rate of N_2 to chamber 630	60	60	60	0	0
Flow rate of H_2 to injector 638	20	30	20	20	40
% by volume of H_2 at:					
A	8	7	8	7	8.5
B	37	40	21	38	52
C	54	57	21	60	72
D	52	58	21	61	72
E	51	58	50	62	72
F	14	18	26	39	43
G	5	7	7	12	13
H	3.5	5	7	6	6
I	2	3	5	5	5
Oxygen potential at: (in mV)					
A	1085	1088	1072	1112	1113
B	1160	1171	1102	1183	1182
C	1191	1199	1112	1218	1200
D	1200	1208	1121	1208	1205
E	1182	1200	1171	1202	1204
F	1160	1174	1173	1201	1197
G	1114	1129	1127	1168	1158
H	1097	1123	1130	1145	1130
I	1067	1103	1112	1133	1125

All flow rates are in cubic feet per hour

CLAIMS

1. A method of heat treating metal in a continuous furnace having in sequence an entrance inlet, a thermal treatment region, a cooling region, and an exit, comprising the steps of substantially preventing ingress of air into the furnace through the entrance and the exit; introducing non-reactive gas (as hereinbefore defined) and reducing gas into the furnace at chosen locations; creating a gas flow regimen within the furnace to provide non-oxidising or reducing conditions substantially throughout the furnace and atmospheres of different compositions in the thermal treatment and cooling regions, and passing the metal through the furnace from the entrance to the exit.

2. A method as claimed in claim 1, in which the continuous furnace is a horizontal furnace.

3. A method as claimed in claim 1 or claim 2, in which gas flow out of the thermal treatment region is substantially in the direction of said entrance rather than the exit.

4. A method as claimed in claim 2 or claim 3, in which non-reactive gas is supplied to the cooling region at one or more locations so as to impede the flow of gases out of the thermal treatment region through the cooling region.

5. A method as claimed in claim 2 to 4, in which non-reactive gas and reducing gas are introduced into the cooling region, the flow regimen being such that a substantial portion of the reducing gas flows into the thermal treatment region.

6. A method as claimed in any one of claims 2 to 5, in which non-reactive gas is introduced into the furnace at one or more locations in the cooling region at or near to the outlet so as to provide a positive flow of gas through the outlet which is effective to prevent or substantially limit the ingress of air into the furnace through its outlet.

7. A method as claimed in any one of claims 2 to 6, in which flow restriction means are located at the outlet so as to impede the flow of air into the furnace without preventing the metal being treated from passing out of the furnace.

8 . A method as claimed in claim 7, in which said means comprises a plurality of curtains, partitions or the like.

9 . A method as claimed in any one of claims 2 to 8, in which a part of the cooling region near to the furnace exit has spaced-apart partitions and/or curtains (or the like) defining at least one chamber adapted to permit metal being treated to pass therethrough and in which non-ctive reactive gas is introduced into the chambers or at least one of the chambers.

10. A method of heat treating metal in a continuous furnace having, in sequence, an entrance , a thermal treatment region, a cooling region and an exit, and also having at or near to at least one end thereof spaced-apart partitions and/or curtains (or the like) defining at least one chamber adapted to permit metal being treated to pass therethrough , said method comprising the steps of introducing a suitable gas or gases into the thermal treatment region to provide a suitable atmosphere for the treatment , supplying non reactive gas to the chamber or chambers so as substantially to prevent ingress of air from outside the furnace through the chamber or chambers into a part of the furnace intermediate the chamber or chambers and the thermal treatment region, and passing metal through the furnace from the

entrance to the exit.

11. A method as claimed in claim 9 or claim 10, in which non-reactive gas is introduced directly into the chamber or chambers.

12. A method as claimed in anyone of claims 9 to 11

$Pc > Pu$ and $Pu > Pa$ where

Pc is the pressure in the chamber or one of the chambers;

Pu is the pressure in the cooling region proximate said chamber or chambers and intermediate said chamber or chambers and the thermal treatment region.

Pa is atmospheric pressure.

13. A method as claimed in claim 14, in which there are at least two chambers and

$Pc > Pu > Pt > Pa$

where Pc is the pressure in the chamber nearest the thermal treatment region:

Pu and Pa are as defined in claim 14,

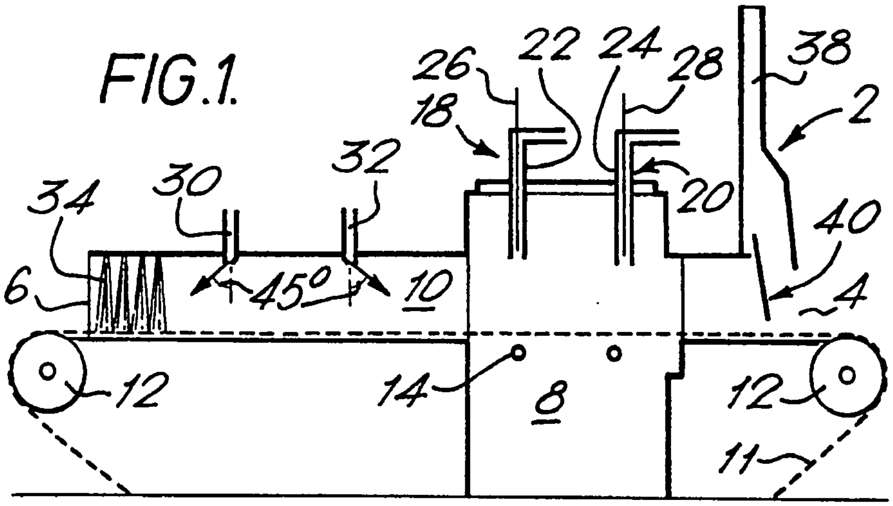
and Pt is the pressure in the thermal treatment region.

14. A method as claimed in any one of claims 9 to 13, in which a relatively high concentration of reducing gas is maintained in a part of the cooling region intermediate the chamber or chambers and the thermal treatment region.

15. A method as claimed in claim 1, in which the furnace is a vertical furnace which has two generally vertical legs intercommunicating at the top, work for heat treatment being passed upwardly through one let ("the up-leg") and downwardly through the other leg ("the down-leg") a thermal treatment region is provided in the down-leg at or near the top thereof , and a cooling region is provided in the down-leg at a region below the thermal treatment region; in which reducing gas is introduced into the cooling region and/or the thermal treatment region, and non-reactive gas is introduced into the up-leg at a plurality of locations so as substantially to prevent the flow of reducing gas into the up-leg; in which non-reactive gas is introduced into both the up and down legs at or near the outlets so as substantially to prevent the ingress of air into the furnace and in which the reducing gas is hydrogen and is introduced solely into the cooling region, the cooling regions and thermal treatment regions containing atmospheres comprising nitrogen and hydrogen, there being a greater proportion of hydrogen in the cooling region atmosphere than in the thermal treatment region atmosphere.

16. A furnace adapted to perform a method claimed in any preceding claim.

FIG.1.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32
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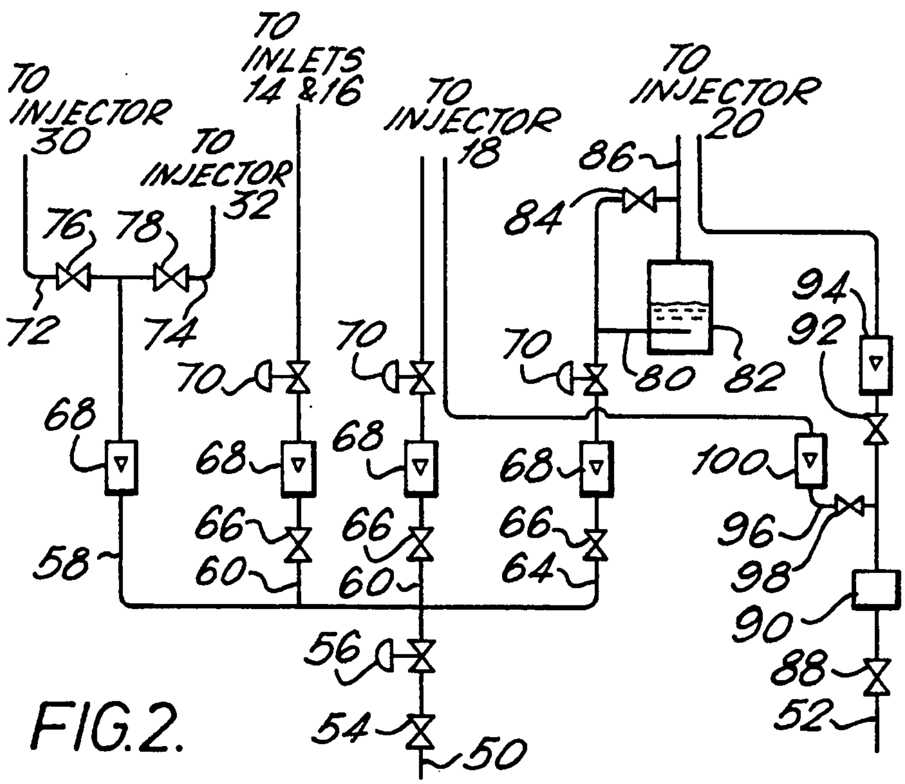
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78
72
74
70
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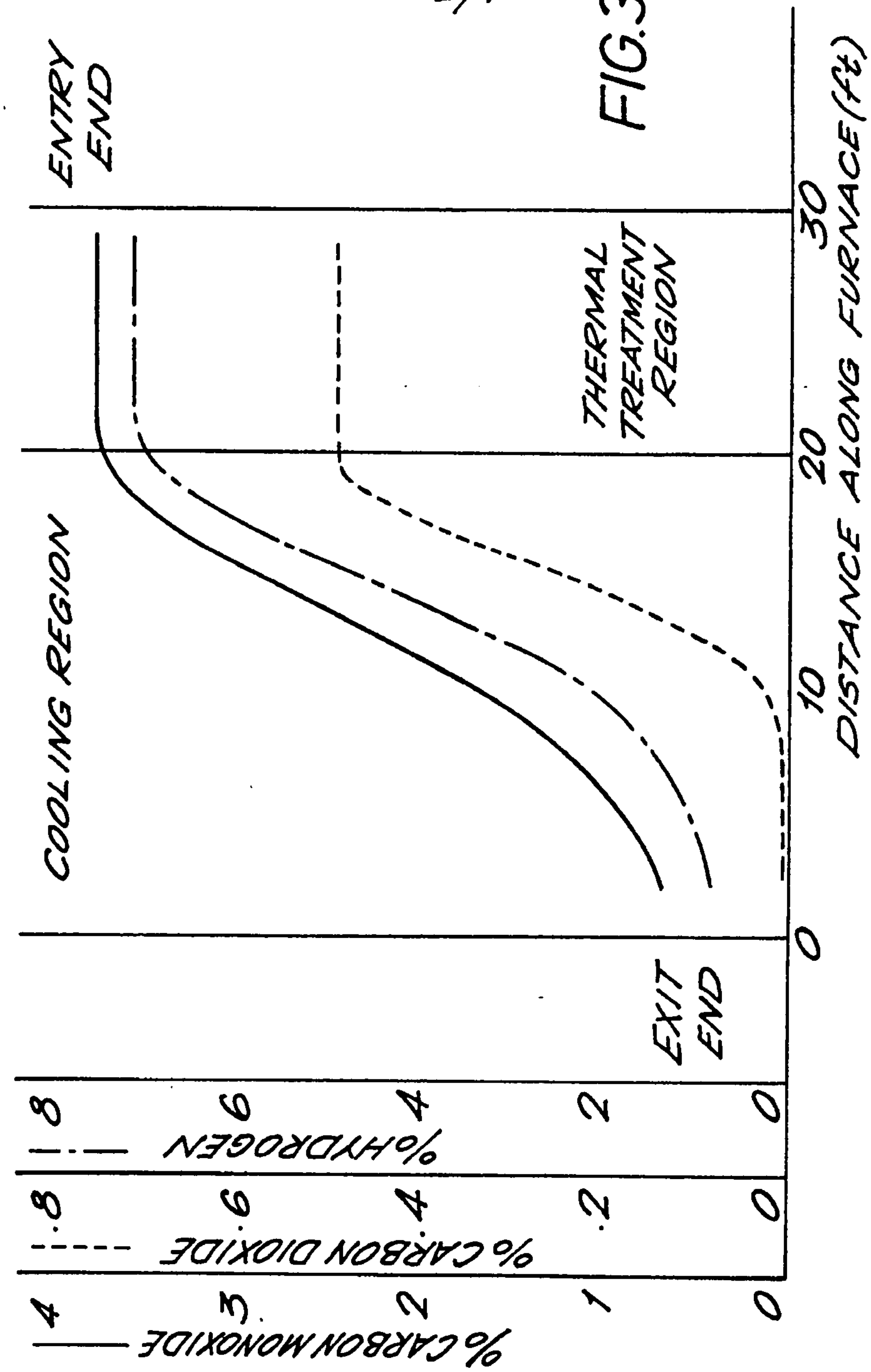
50

FIG.2.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THERMAL TREATMENT REGION
EXIT END
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10
20
30
%HYDROGEN
0
2
4
6
8
%CARBON DIOXIDE
0
.2
.4
.6
.8
%CARBON MONOXIDE
0
1
2
3
4

FIG.3.

3/4

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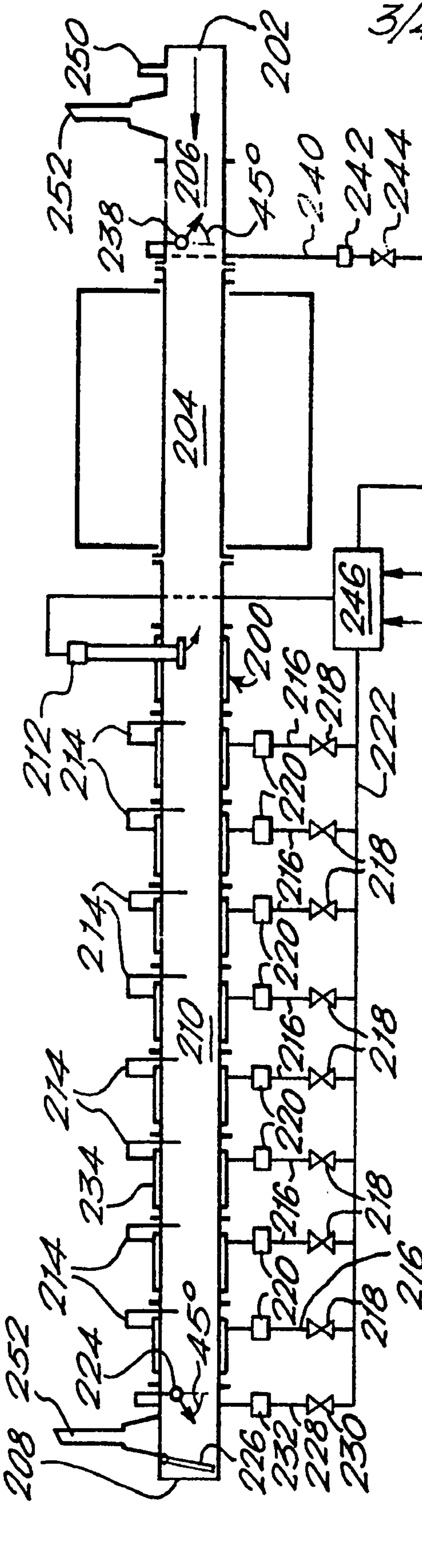


FIG.4.

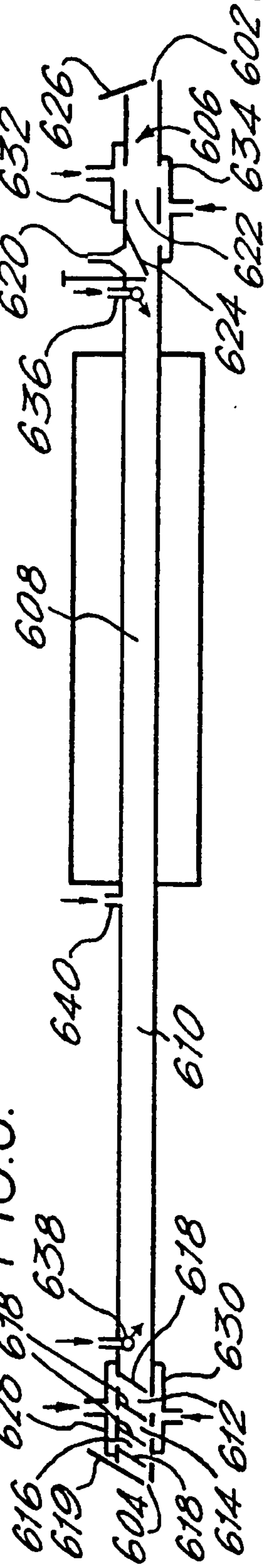
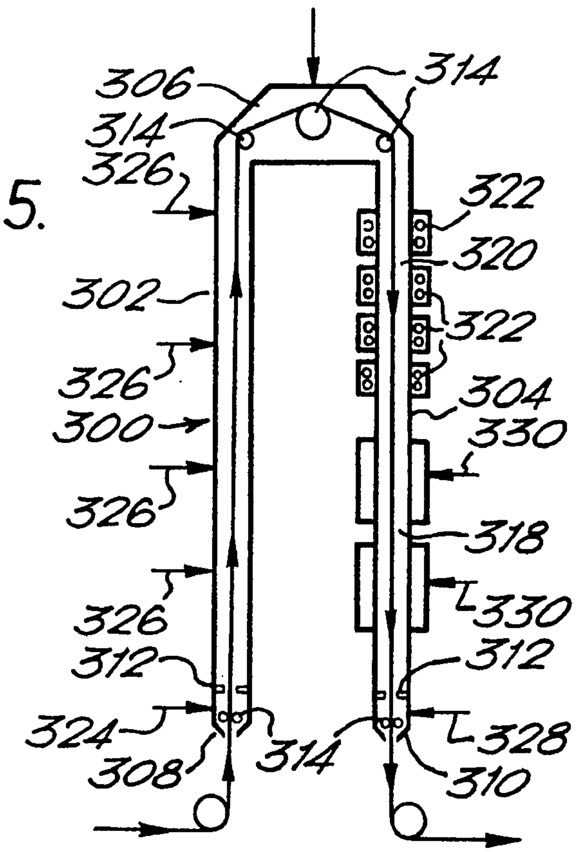


FIG.6.

FIG.5.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318
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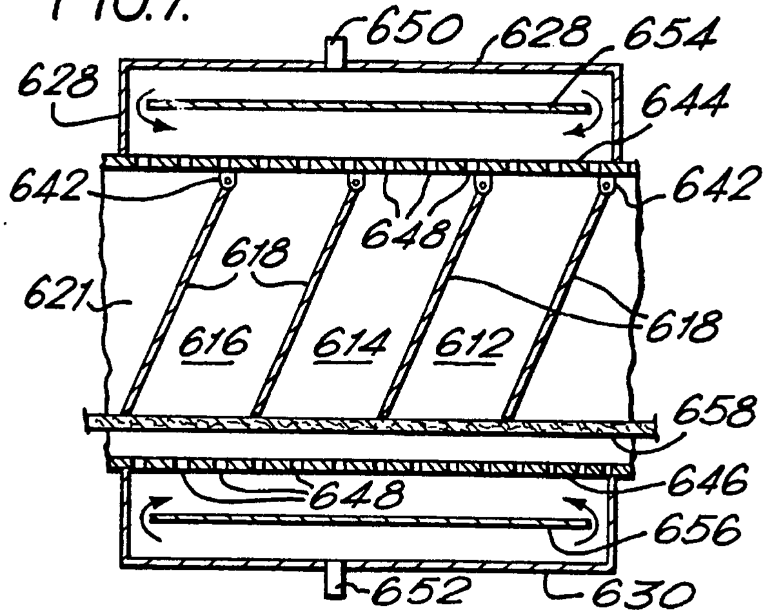
FIG.7.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European Patent Office

EUROPEAN SEARCH REPORT

0075438

Application number

EP 82 30 4867

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
X	GB-A- 429 940 (J.L. PEARSON et al.) * the whole document *	1-5,7, 8,16	C 21 D 1/74 C 21 D 9/56 // C 21 D 1/76
X	US-A-3 467 366 (H.W. WESTEREN et al.) * the whole document *	1,2,4, 5-11, 16	
X	FR-E- 55 831 (M. ALFERIEFF) * the whole document *	1-7,16	
A	GB-A- 515 121 (W. DODERER)		
A	GB-A- 695 624 (BIRLEC et al.)		TECHNICAL FIELDS SEARCHED (Int. Cl. 3)
A	US-A-3 950 192 (D.I. GOLLAND et al.)		C 21 D
A	DE-C- 617 319 (BENNO SCHILDE)		
A	DE-C- 861 569 (ACCUMULATORENFABRIK)		
A	GB-A- 794 140 (METALROLLING AND TUBE CO.)		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	14-12-1982	MOLLET G.H.J.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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